tical, proving conclusively that the deuterated nucleoside obtained by Reichard in the *in vitro* reduction was indeed **4**, as suggested earlier.[9,10]

Enzymic reduction of ribonucleotides therefore occurs with retention of configuration at carbon 2′. It is interesting to note that this stereochemical outcome is reminiscent of catalytic hydrogenolysis of alcohols, which proceeds with predominant retention of configuration[19] and the opposite of ionic (hydride) deoxygenations which proceed in an SN2 manner.[20]

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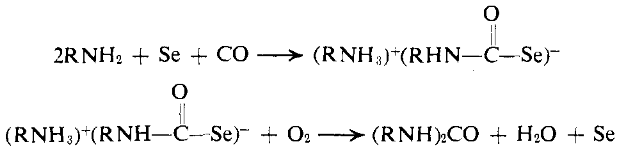
A New Synthesis of Ureas. The Reaction of Ammonia or Aliphatic Amines with Carbon Monoxide in the Presence of Selenium

Sir:

Early reports describe the synthesis of ureas from primary amines or ammonia and carbonyl sulfide[1-3] (or elemental sulfur and carbon monoxide[4-6]). In general high temperatures and pressures are required for primary amines, while secondary amines do not react. In this communication we report the general synthesis of ureas from aliphatic amines, carbon monoxide, and oxygen using selenium as a catalyst. The conditions required are mild and secondary amines can be used. The following procedure for the preparation of 1,3-di-*n*-butylurea is representative.

In a typical reaction, 0.1 mol of *n*-butylamine was dissolved in 100 ml of tetrahydrofuran; to the solution a 0.40-g sample (0.005 g-atom) of amorphous selenium[7] was added, and carbon monoxide was blown into the resultant suspension at a rate of 60 ml/min for about 5 min; the selenium dissolved completely. Thereafter, oxygen[8] was blown through the solution at a rate of 9 ml/min for 4 hr; the bubbling of carbon monoxide was also maintained. Finally the flow of carbon monoxide was stopped and oxygen flow was continued to precipitate the selenium. Removal of the recovered selenium and the solvent gave 1,3-di-*n*-butylurea in stoichiometric yield. An increase in the rate of oxygen addition during early stages of the reaction (20 ml/min) caused the deposition of elemental selenium and hence stopped the formation of the urea. Using a temperature of 20° and 1 atm of CO pressure, we prepared ureas from *n*-butylamine, *n*-hexylamine, *n*-octylamine, and cyclohexylamine in yields ranging from 95 to 99%. With ethylenediamine, benzylamine and piperidine, yields under these conditions were 14, 74, and 26%. Under more stringent conditions ($T = 60°$; CO, $P_{\mathrm{atm}} = 50$; Se, 0.05 g-atom), ethylenediamine gave a 98% yield of 2-imidazolidone and 1,3-propylenediamine ($T = 40°$; CO, $P_{\mathrm{atm}} = 50$; Se, 0.05 g-atom) gave a 96% yield of *N*,*N*′-trimethyleneurea.

Isolation of selenocarbamate salts as intermediates provides strong evidence that the process goes in at least two steps. These can be summarized by the equations

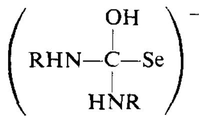


$$2RNH_2 + Se + CO \longrightarrow (RNH_3)^+(RHN{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}Se)^-$$

$$(RNH_3)^+(RNH{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}Se)^- + O_2 \longrightarrow (RNH)_2CO + H_2O + Se$$

The *N*-*n*-butyl selenocarbamate was very sensitive to oxidation while the *N*,*N*-pentamethylene selenocarbamate (or *N*-piperidyl selenocarboxylate) was significantly more stable. The latter compound would also react with excess piperidine to give the expected urea and piperidinium hydroselenide, $(C_5H_{12}N)^+(HSe)^-$.

Unsymmetrical urea can be synthesized from the intermediate salt. The reaction of the *N*-*n*-butyl selenocarbamate salt with piperidine in THF at 20° followed by air oxidation gave 98% yield of the expected unsymmetrical urea. Similarly, the reaction of the *N*,*N*-pentamethylene selenocarbamate with *n*-butylamine followed by air oxidation gave a stoichiometric yield of the unsymmetrical urea. The mechanism of mixed urea formation is being investigated. It is currently suggested that an intermediate anion of the form



$$\left(\begin{array}{c} OH \\ | \\ RHN{-}C{-}Se \\ | \\ HNR \end{array}\right)^-$$

may be important. It is also probable that carbonyl selenide (SeCO), prepared from CO and Se in the presence of a base such as pyridine, is an active intermediate. When CO and Se were combined in the presence of a pyridine solution and the issuing gas stream was introduced into a solution of *n*-butylamine, equimolar amounts of 1,3-di-*n*-butylurea and Se were isolated from the solution by air oxidation. No product was obtained without pyridine in the original solution. The data suggest that SeCO was formed in the pyridine solution and carried into the *n*-butylamine solution.

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[7] It was also possible to use metallic selenium; however, it dissolved more slowly into the solution.

[8] Air can also be used.